ON THE POSSIBILITIES OF MEASURING THE GLUON DISTRIBUTION USING "γ/Z^0+JET" EVENTS AT TEVATRON RUN II AND LHC.

D.V. Bandurin[1], N.B. Skachkov[2]

Joint Institute for Nuclear Research, Dubna, Russia

E-mail: (1) dmv@cv.jinr.ru, (2) skachkov@cv.jinr.ru

The number of "$\gamma + jet$" and "$Z^0 + jet$" events suitable for a determination of gluon distribution function in a proton $f_p^g(x, Q^2)$ at Tevatron Run II and during the low luminosity runs at future LHC experiments are estimated for various intervals of x and Q^2. These numbers allow to extract $f_p^g(x, Q^2)$ in new kinematic regions of $2 \cdot 10^{-3} \leq x \leq 1.0$ with $1.6 \cdot 10^3 \leq Q^2 \leq 2 \cdot 10^4 \ (GeV/c)^2$ at Tevatron and of $2 \cdot 10^{-4} \leq x \leq 1.0$ with $1.6 \cdot 10^3 \leq Q^2 \leq 2 \cdot 10^5 \ (GeV/c)^2$ at LHC. The contributions of background events in different Q^2 intervals are also given.

1   Introduction.

To study the possibilities of getting out the information about the gluon distribution from inclusive photons [1] and from "$\gamma/Z^0 + jet$" events [2–5] measured in pp or $p\bar{p}$ collisions we estimate here the numbers of events that can be collected during the nearest 2–3 years of running with the planned luminosity at Tevatron Run II and LHC (at $L = 10^{33}s^{-1}cm^{-1}$) experiments as well as the contribution from the background events. The process $pp(p\bar{p}) \rightarrow \gamma/Z^0 + 1\,jet + X$, we are studying, is caused at the leading order by the following subprocesses:

$$qg \rightarrow q + \gamma/Z^0 \ \ (1a), \qquad q\overline{q} \rightarrow g + \gamma/Z^0 \ \ (1b).$$

The results presented here are heavily based on the studies done in [2–5] where the event selection criteria of events with a clean "$\gamma/Z^0 + jet$" topology and most suitable for jet energy scale setting at Tevatron and LHC were developed. Our estimations are done mainly within the framework of PYTHIA event generator [6] and complemented by detector response simulations while studying a possibility of the background events rejection [7, 8] [1].

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[1] The geometry of D0 and CMS detectors are used for all presented estimations.

2   The background estimation.

To estimate a background to the signal events, we have done by three generations (each of about 40 million events) with a mixture of all QCD and SM subprocesses existing in PYTHIA including subprocesses (1a) and (1b). Each event generation was done for three different values of minimal transverse momentum of a hard subprocess $\hat{p}_{\perp}^{min}$: 40, 70, 100 GeV/c for Tevatron and 40, 100, 200 GeV/c for LHC.

The background to the "$\gamma + jet$" events is mainly caused by the events with high P_t photons produced in the neutral decay channels of π^0, η, ω and K_s^0 mesons ("$\gamma-mes$" events) and by the events with the photons radiated from quarks (i.e. bremsstrahlung photons) in the next-to-leading order QCD subprocesses ("$\gamma-brem$" events).

The background may be also caused by "$e^{\pm}$ events" containing one jet and $e^{\pm}$ as a direct photon candidate. The fraction of these events in the total background turns out to be negligibly small after application of all selection cuts (including the cut on the missing transverse momentum in an event) and the account of the tracker information.

The selection criteria of the "$\gamma + jet$" events are described in detail in [2, 3, 5]. In is worth mentioning among them only two new ones, not used earlier in previous experiments. They leave only the events having small values of cluster (mini-jet) transverse momenta, i.e. P_t^{clust}, and the modulus of a vector sum of transverse momenta of all detectable particles that are out of "$\gamma + jet$" system, i.e. P_t^{out}, by limiting them from above by 10 GeV/c [2].

The obtained after application of the selection cuts the signal-to-background (S/B) ratios are presented in Table 1 [3].

Table 1: S/B at Tevatron and LHC.

$\hat{p}_{\perp}^{min}$ (GeV/c)	40	70	100	40	100	200
S/B	2.9	8.8	21.1	4.1	22.4	47.0

The estimations in PYTHIA have also shown that most of "$\gamma-brem$" and "$\gamma-mes$" events (80% at least) originate from $qg \rightarrow qg$ and $qq \rightarrow qq$ scatterings with dominant contribution from the first subprocess $(60-70\%)$ [5].

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[2]The selection criteria (mostly the two of them that limit P_t^{clust} and P_t^{out} [2, 3, 4] allow the events with a good P_t^{γ} and P_t^{jet} balance to be selected because they provide an essential initial and final state radiation suppression, i.e. a suppression of the contribution of the next-to-leading order diagrams.

[3]They are given without account of the contribution from the "$e^{\pm}$ events" [2, 3, 5].

3 Event rate estimation for gluon distribution determination at the Tevatron Run II and LHC.

The rates of the selected $qg \to \gamma q$ events are presented in Table 2 for the case of Tevatron (at integrated luminosity $L_{int} = 3\ fb^{-1}$) for different intervals of $Q^2 = (P_t^\gamma)^2$ and parton momentum fractions x. The corresponding rates of $qg \to \gamma q$ events for the case of LHC (calculated with $L_{int} = 10\ fb^{-1}$) are shown in Table 3. The fractions of each event type in a given interval of $P_t^{\tilde\gamma}$ are presented in Fig. 1 (100% are taken for all events) for a case of LHC.

Table 2: Numbers of "$qg \to q+\gamma$" events (divided by 10^3) in Q^2 and x intervals for $L_{int} = 3\ fb^{-1}$. Tevatron.

Q^2	x values of a parton					All x
$(GeV/c)^2$	.001–.005	.005–.01	.01–.05	.05–.1	.1–1.	.001–1.
1600-2500	8.6	56.3	245.2	115.9	206.6	632.6
2500-4900	0.4	13.5	119.3	64.4	123.0	320.7
4900-8100	0	0.2	17.9	13.5	27.4	59.0
8100-19600	0	0.0	3.8	5.6	12.0	21.5
					$(10^3\times)$	**1 034**

Table 3: Numbers of "$qg \to q+\gamma$" events (divided by 10^3) in Q^2 and x intervals at $L_{int} = 10\ fb^{-1}$. LHC.

Q^2	x values of a parton				All x
$(GeV/c)^2$	10^{-4}–10^{-3}	10^{-3}–10^{-2}	10^{-2}–10^{-1}	10^{-1}–10^0	10^{-4}–10^0
1600-2500	830.7	2503.8	2577.6	221.3	6133.3
2500-5000	358.0	1497.9	1615.2	233.8	3704.8
5000-10000	36.0	380.3	415.7	116.5	948.4
10000-20000	1.9	84.8	98.9	46.1	231.7
20000-40000	0.0	16.9	24.9	13.3	55.1
40000-80000	0.0	2.9	5.4	3.8	12.0
				$(10^3\times)$	**11 084**

The estimations of event rates with a charm quark $gc \to \gamma c$ at Tevatron and LHC are given in [2, 3] [4].

The discrimination efficiencies of a single photon from the π^0, η, K_s^0 mesons (decayed via neutral channels) as well as those between quark and gluon jets allows to increase noticeably the purity of "$\gamma^{dir} + jet$" events [5, 8].

Another possibility to extract a gluon distribution in a proton is a usage of "$Z^0 + jet$" events with the subsequent Z^0 decay via leptonic (l^+l^-) channels.

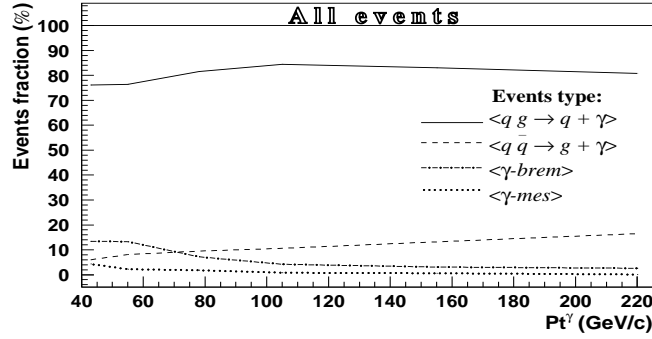[4]They give approximately 14 times less number of events.

Figure 1: The contributions of various event types to the total number of events as a function of $P_t{}^\gamma$.

The selection criteria guarantee practically complete suppression of the background events [4]. The distribution of the number of the "Z^0+jet" events, originated from subprocess $qg \to Z^0 + q$ (with the decay $Z^0 \to \mu^+\mu^-, e^+e^-$) over Q^2 and x intervals are given in Table 4 for the case of LHC at $L_{int} = 20\ fb^{-1}$.

Fig. 2 shows a kinematic plot with the area that can be covered by studying the process $qg \to \gamma q$ at Tevatron and LHC. The distribution of events inside this area is given in Tables 2 and 3. It is seen that at Tevatron (full line) and at LHC (dashed line) it would be possible to study the gluon distribution on a good statistics of "$\gamma + jet$" events in the region of small x at values of Q^2 that are about by $1 - 2$ orders of magnitude higher than those that are reached at HERA now. It is also worth emphasizing that the $x - Q^2$ region covered by Tevatron has a common region with HERA at $0.05 < x < 0.5$.
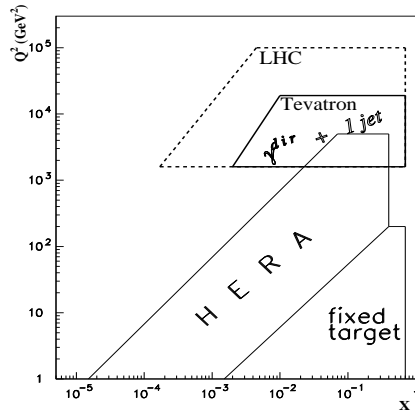
Such a overlapping allows to carry out the cross-check of the $f_p^g(x,Q^2)$ measurements at Tevatron and HERA. The data from Tevatron, in their turn, will be important for analogous cross-check of the $f_p^g(x,Q^2)$ measurements at LHC (see Fig. 2). So, the data from Tevatron combined with ones from HERA and with the future data from LHC would allow to fulfill the QCD analysis in Q^2 region varying in the wide interval of $10^2 < Q^2 < 10^5\ GeV^2$.

Figure 2: Kinematic region for $pp(\bar{p}) \to \gamma + jet + X$ process at Tevatron and LHC.

Table 4: Numbers of "$gq \to Z^0 + q$" events (with $Z^0 \to \mu^+\mu^-, e^+e^-$) in Q^2 and x intervals for $L_{int} = 20 \ fb^{-1}$. LHC.

Q^2	x values of a parton				All x
$(GeV/c)^2$	10^{-4}–10^{-3}	10^{-3}–10^{-2}	10^{-2}–10^{-1}	10^{-1}–10^0	10^{-4}–10^0
900-1600	19563	55852	59257	2838	137510
1600-2500	8627	38407	40262	2422	89718
2500-5000	5108	37197	45256	4276	91837
5000-10000	530	19866	25391	3368	49154
10000-20000	38	6735	11882	1968	20623
20000-40000	0	1324	3746	1097	6168
					395 010

Acknowledgments

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